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ONTARIO
DEPARTMENT OF
EDUCATION

General and Advanced Levels of Instruction in Grade 13 Physics

JANUARY, 1966

As recommended by the General and Advanced Committee which conducted part of the Grade 13 studies, the suggested outlines listed below have been prepared at the direction of the Minister of Education by the Curriculum Division with the assistance of university and secondary school personnel. The outlines are to be considered as working papers rather than definitive courses. It is expected that they would be subject to further development and change if it is decided to submit them to field testing. They are being distributed to the universities and to the secondary schools for evaluation.

GA. 31 Accountancy and Secretarial Studies

GA. 13 Art

GA. 17B Biology

GA. 11 Classics

GA. 18 Chemistry

GA. 4 English

GA. 46 français

GA. 15A French

GA. 17E General Science

GA. 7 Geography

GA. 15B German

GA. 9 History

GA. 12 Mathematics

GA. 16 Music

GA. 17C Physics

BROAD SUGGESTED OUTLINES OF GENERAL AND ADVANCED COURSES IN PHYSICS

A. GENERAL LEVEL PHYSICS

1 Preamble

Within the framework of the General and Advanced structure, this course is intended as an elective for students who probably are not taking any other Grade 13 Mathematics or Science, and who may not have completed all the Grade 11 and 12 courses in Physics, Chemistry and Mathematics. The Committee believes that the students electing General Level Physics would be drawn from (i) students not planning to go to university, (ii) students planning for teachers' colleges or the projected community colleges, (iii) students planning for admission to social science and humanities' courses in university.

The students taking this course will not, in general, think easily in the symbolic language of mathematics, and will not be interested in gaining the professional point of view of the scientist or engineer who has learned to apply mathematical skills to physical problems. The course program for the General Level course should recognize this fact, and aim at helping the students enrolled in it to gain some insight into the way in which science develops. It should lead them to an appreciation of the fact that science is an exercise of the human mind which depends for its development on the same qualities of imagination, insight, objectivity, and creativity that are necessary for mastery of the disciplines of literature, music, art, etc. etc.

There will be a considerable temptation in the schools in the minds of both students and teachers to regard the General Level course in physics as a "watered-down" version of the Advanced Level course. In order to avoid this, the committee feels that the General Level course should differ significantly from the Advanced Level course, including much material that will not be taught in the Advanced Level program. The committee feels strongly that a course which concentrates on learning facts of science would be quite undesirable; both because scientific facts and their interpretation change over the years, and because the range of physical phenomena is so vast that any selection aimed to touch on all the major branches of physics would leave the student with no insight into the methodology of science. Inasmuch as graduates of this course will eventually be found in the ranks of the leaders of society, it is more important that they understand the attitudes of science and scientists than that they know a few facts about science.

The Committee therefore recommends that the General Level course in Physics should tell a story, and be planned to exclude from its purview anything which has no bearing on this story. This story should be different from the PSSC story which we are recommending for the Advanced Level course in Physics, but it should be equally exciting. From purely practical considerations it would be desirable that the two stories should be sufficiently related so that the schools might use the same laboratory equipment, and many of the same experiments, for both courses.

The Committee therefore recommends that the theme of the Grade 13 General Level course in Physics be "the Universe Around Us" or "Physics in Astronomy".

Man's developing awareness of the nature of the universe of outer space has been a result of the development of physics; in fact, professional training in astronomy can only be undertaken *after* a person has become a trained physicist. Almost all the information that comes to us from outer space comes to us by means of light or radio signals, and the interpretation of this information is made on the basis of our knowledge of the way in which light is produced and transmitted. The down-to-earth portion of this course syllabus will be a study of those properties of light which have some bearing on an understanding of stellar phenomena. A sufficient number of inexpensive laboratory experiments which fit into this context can be devised; in fact, most of them would use the same equipment as that required for the proposed Advanced Level course, whose story-line is "The Nature of the Atom". The more descriptive portions of the courses dealing with the stars can be illustrated by star-viewing sessions, by the use of a Spitz planetarium, by the use of films, and by using prints of photographs from astronomical observatories.

The following outline is presented as a guide for the concept developed above. The preparation of a detailed course outline will require the active participation of practising astronomers as well as physicists and high school teachers. The committee charged with drawing up such a curriculum would need to have frequent meetings, would have to arrange for the publication of a textbook, make a carefully selected bibliography of source materials for teachers and students, and make a critical selection of experiments and films suitable for this course. Undoubtedly, the detailed curriculum prepared by such a committee would need to be tested in a number of high school pilot projects and modified before being adopted.

2 Course Outline

Unit I DESCRIPTIVE ASTRONOMY (4 WEEKS)

This unit should provide the student with the historical and scientific orientation he needs for his exploration of the universe. It should include discussion of celestial mapping, the development of the calendar and measurement of time, the apparent motions of the sun, moon and planets, the controversy between the heliocentric and geocentric views of the solar system, the identification of the major constellations.

This section should be completed early in the fall term, before the weather has become too severe for outdoor viewing.

Unit II THE PROPERTIES OF LIGHT (6 WEEKS)

This unit should provide the basic knowledge of electromagnetic radiation necessary to interpret stellar phenomena. It will have to include geometric optics, physical optics and wave motion, some of the concepts of atomic structure, and the laws of radiation. It should not be taught as one unit but the material should be interspersed with material drawn from the astronomical portion of this course.

The following should be among the topics covered (the letter E after a topic indicating that it should be taught in conjunction with laboratory experience): measurement of the velocity of light, laws of reflection and refraction (E), properties of wave motion as seen with a ripple tank (E), the controversy between particle and wave views of light propogation, image formation by mirrors, lenses, and telescopes (E), the f-ratings of lenses and cameras, diffraction of light (E), the limitation imposed on the performance of lenses by diffraction (E), the Doppler effect, inverse square law.

The production of light, and the origins of line, band, continuous and absorption spectra (E), laws of black body radiation, the Bohr atom.

Unit III THE SOLAR SYSTEM (4 WEEKS)

Law of gravitation, Kepler's laws, realities of space travel, physical properties of the planets, and the size of the solar system.

Unit IV MEASUREMENT OF DISTANCES (4 WEEKS)

The methods of measuring distances into space should proceed through triangulation and parallax methods to the use of Cepheid variables.

Unit V STELLAR PHENOMENA AND ENERGY SOURCES IN STARS (4 WEEKS)

Stellar magnitudes, the sun as a typical star, radial velocities of stars, stellar spectra, stellar populations, star clusters, Cepheid variables, interstellar material, etc. etc.

The discussion of energy sources will require building up a limited background in nuclear physics and should go on to a discussion of the carbon cycle and proton proton cycle.

The section will end with discussions of the Russell-Hartsprung diagram and stellar evolution.

Unit VI THE GALAXIES, THE SIZE OF THE UNIVERSE AND COSMOLOGY (4 WEEKS)

The size, number, and distribution of galaxies, the continuous theory of creation versus the "big bang" theory. The course should end on open-ended questions of cosmology.

3 Reference Texts

Books such as the following would be useful as reference texts:

a) *From Atoms to Stars* — T. Ashford — Holt
b) *Exploration of the Universe* — Abell — Holt

B. ADVANCED LEVEL PHYSICS

1 Preamble

The Committee for Physics at the General and Advanced Levels has designed the Advanced Level Physics course primarily for students who intend to major in mathematics, science, or engineering in university. Such students will be expected to have an aptitude for thinking in mathematical terms. While the course depends on mathematics only to the end of Grade 12, it is expected that these students will be enrolled in Advanced Level Mathematics in Grade 13.

In the present era, with knowledge expanding so rapidly, it is impossible to organize a secondary school course in physics which gives comprehensive coverage to all aspects of the subject. Since the understanding of scientific methods is more important than the memorization of many facts, the committee has considered the development of scientific procedures and the comprehension of physical concepts to be of prime importance in the course.

The committee considers that the course which best meets the essential requirements for Advanced Level Physics is the one developed by the Physical Science Study Committee (1965 editions of *Physics* and *Laboratory Guide*). This course is the culmination of many years of development and trial by men of ability and is already in use in an abridged version in the secondary schools of Ontario. By the use of the full, unabridged course, it will be possible to gain maximum benefit of the original conception.

The P.S.S.C. course is designed to tell a story, and areas of physics that are not essential to its telling are omitted. As a result it is hoped that the course may be taught in such a way as to realize the culmination of the story in the modern atomic theory of matter. The topics in the course are selected and ordered to progress from the simple and familiar to the more subtle ideas of modern atomic physics. In this way, physics is presented, not as a mere body of facts, but basically as a continuing process by which men seek to understand the nature of the physical world.

2 Course Outline

Unit I THE UNIVERSE

This unit presents a general introduction to the fundamental physical concepts of time, space, motion, and matter. The kinematics of velocity and acceleration is studied with an emphasis on the graphical analysis of experimentally determined data. Vector analysis of the components of velocity and acceleration is also introduced. The unit concludes with a first look at the atomic and molecular composition of matter. In this way fundamental concepts and techniques are established that are essential for the students' understanding of later parts of the course.

Unit II OPTICS AND WAVES

Light has been chosen as the first branch of physics to be studied in detail. Not only does this study relate to the many familiar phenomena, but it also provides a direct route to modern physical ideas. After an examination of reflection and refraction at optical boundaries, a particle model for light is developed. This discussion illustrates a major aspect of the procedures by which scientific knowledge is constructed.

"Under continued scrutiny the particle model proves inadequate, and the student finds that we need another model—a wave model. The laboratory . . . provides an unexcelled source of experience, and here the student becomes familiar with the properties of waves. . . . He begins to recognize the group of characteristics that constitute wave behaviour. Knowledge of interference and diffraction comes directly from a study of waves in a ripple tank. For the first time, perhaps, the smears of light around street lamps, the colours of oil slicks, and the formation of images by lenses appear as aspects of

the wave nature of light."* This study lays the foundation for a later examination of the wave and particle aspects of both matter and radiation.

Unit III MECHANICS

Motion is examined from a dynamical point of view. Newton's laws of motion are developed with the aid of simple laboratory apparatus. The laws of gravitational attraction, conservation of momentum, and conservation of energy are introduced through a combination of theory and laboratory exploration. The unit concludes with an application of energy principles to improve the understanding of the behaviour of gases. The concepts developed in this unit provide further foundations for the development of an understanding of the structure of matter.

*from Preface to *Physics 1965,* by P.S.S.C. p. vi

Unit IV ELECTRICITY AND ATOMIC STRUCTURE

This unit introduces students to electricity, and through it to the physics of atoms. Using the knowledge of dynamics gained in Unit III, they are led to a quantitative study of the forces between electrical charges, and to the motions of charged particles in electric fields. The results of this study are applied to the measurement of the charge on the electron, and the masses of electrons, protons, and atoms. Finally, magnetism is introduced as a phenomenon associated with the motion of electric charges. Through an exploration of the laws of induction, students are given a qualitative feeling for the electromagnetic nature of light.

The second portion of this unit draws on much of the material treated in the earlier parts of the course to build up a picture of the currently accepted model of the structure of atoms. In this process, students are introduced to Rutherford's experiments which led to the nuclear model of the atom; the duality of wave and particle explored by de Broglie and others; and the structure of the hydrogen atom and its excited states as viewed originally by Bohr, and as modified by the more modern theories of quantum mechanics.

The first part of Unit IV is strongly supported by student-conducted experiments. For the second part, where direct experience is more difficult and more expensive, films have been produced to provide evidence of the experimental foundations of modern theories.

C. ADVANCED LEVEL PHYSICAL SCIENCE

1 Introduction

As discussions progressed concerning the General and Advanced Level Program, meetings were held by the chairmen of the departments of physics and also by the chairmen of the departments of chemistry of the Ontario universities to assess the consequences of this program for university courses.

The views of the above two groups were conveyed to the General and Advanced Chemistry and Physics Committees. It was apparent that if the General and Advanced Level concept were introduced into Grade 13 both university groups would expect that Advanced Level Mathematics would be studied as a prerequisite to university studies in chemistry and physics. Furthermore, if the additional stipulation were made that two Advanced and two General Level courses were required for university entrance, then under this condition, both groups would favour a combined Physical Science course as the second Advanced Level course for students planning to continue studies in chemistry or physics at university. It was felt that the common areas of study in chemistry and physics would make such a course feasible. This proposal reflects the view which appears to be widely accepted, that all candidates for admission to science courses at university should follow essentially the same program in Grade 13.

In order to enable both the General and Advanced Level Physics and Chemistry Committees to proceed with their separate tasks, a sub-committee consisting of members of each of the aforementioned committees was formed to investigate the possibility of presenting a Physical Science course, and to make a report to these committees.

The report of this sub-committee is presented below, followed by an account of the opinions expressed by both the General and Advanced Level Chemistry and Physics Committees.

2 Preamble

An integration of physics and chemistry into a single Physical Science course is based upon the mutual support the two separate sciences provide to each other in the pursuit of understanding of the fundamental structure of matter. In fact, the genesis of the basis of our present understanding, during the period from 1890 to 1930, was the result of a combined onslaught by physicists and chemists without concern for formal subdivisions. At the Grade 13 stage in a student's career, he could well be given ample opportunity to experience the interaction of the ideas contributed by both chemists and physicists. In particular, energy concepts developed from a physical point of view can provide a firmer foundation for the understanding of chemical reactions than would be possible without it. At the same time, the electronic basis of the periodic arrangement of the elements depends on a wealth of knowledge of chemical properties. When courses in chemistry and physics arrive at the details of atomic structure they are covering common ground.

The essence of the structure of this course is the provision of the understanding of fundamental concepts at each point as they are required to deepen the students' grasp of the next level of penetration into the details of the structure of matter. The topics that are listed in the outline below have been taken from *Physics,* by the Physical Science Study Committee, and from *Chemistry, An Experimental Science,* by the Chemical Education Materials Study. It is intended that, at least during the trial period, these two textbooks would form the basis of the course. As many as possible of the topics have been omitted to make it possible to handle the material in a single year. At the same time, enough must be retained to present a connected story of the investigation of the nature of matter.

During the trial period, at least, two teachers would likely be required for each class: one with a strong background in chemistry, and the other in physics. It is essential for the trial teachers to have a sufficient depth of understanding of these two sciences so that they can make day-to-day decisions about the presentation of the material and the directions of course development. During the trial period these teachers would have to determine how much of the material can be presented in a satisfactory manner in the available time. They would have to consult with others to consider which topics might be deleted if required. At the same time, the trial teachers should participate in training programmes that have as their objective the preparation of teachers able to handle the Physical Science course by themselves.

3 Course Outline

The following course outline is based upon experimentation being conducted by certain science teachers in Oregon, U.S.A., in conjunction with the National Science Teachers Association.

Unit 1 INTRODUCTION

1 Analysis of data
2 Time and its measurement
3 Space and its measurement
4 Motion along a straight-line path
5 Motion in space (vectors)
6 Molecules in the gas phase
7 Condensed phases of matter
8 Atomic structure and the periodic table

Unit 2 MECHANICS

1 Newton's law of motion
2 Motion at the earth's surface
3 Universal gravitation
4 Momentum and the conservation of momentum
5 Work and kinetic energy
6 Potential energy

Unit 3 HEAT AND ENERGY

1 Energy effects in chemical reactions
2 Heat and molecular motion

Unit 4 CHEMICAL REACTIONS

1 The rates of chemical reactions
2 Equilibrium in chemical reactions
3 Solubility equilibria
4 Aqueous acids and bases
5 Oxidation-reduction reactions
6 Chemical calculations

Unit 5 WAVE MOTIONS

1 Introduction to waves
2 Waves and light
3 Interference
4 Light waves

Unit 6 ELECTRICITY

1 Some qualitative facts about electricity
2 Coulomb's law and the elementary charge

Unit 7 ATOMS AND THE STRUCTURE OF MATTER

1 Exploring the atom
2 Photons and matter waves
3 Quantum systems and the structure of atoms
4 Electrons and the periodic table
5 Covalent bonds and molecular architecture
6 Bonding in solids and liquids

The following is a tentative suggestion for a time schedule, to indicate the relative emphasis intended for each of the areas of study. Anything more precise or detailed than this would have to be developed by the trial teachers. The hour assignments are based on the six hours per week proposed by the General and Advanced Level Committee for Advanced Level subjects.

Section	Number of hours
A	36
B	36
C	8
D	36
E	14
F	8
G	36
	174

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4 Comments of the Committees

(a) The General and Advanced Chemistry Committee

The view was expressed by at least one member of the Chemistry Committee that the approach of the chemist and the physicist are philosophically different, and hence these two subjects do not lend themselves to amalgamation at the Grade 13 level.

It was also argued by another member that the degree of sophistication in the teaching of both subjects at the Grade 13 level was such that the amalgamation of the two would be feasible and even desirable.

After much discussion concerning the advantages and disadvantages of a combined Physical Science course the following conclusion was reached by a majority of the members:

"The evidence produced to date is not sufficient to justify the trend towards the blending of Physics and Chemistry into one course in secondary schools at this time.

"The problems involved, including the lack of teachers with adequate background in both Physics and Chemistry, the special laboratory arrangements required, the lack of sufficient background of the students in either Physics or Chemistry to enable them to appreciate the significance of the inter-relationship of the two areas of study, leads us to conclude that implementation of one course in Physical Science should be approached with extreme caution.

"We, therefore, recommend that there be separate courses in Chemistry and Physics in Grade 13."

(b) The General and Advanced Physics Committee

The members of the Physics Committee also stressed the necessity of approaching a Physical Science Course with great care.

This committee was generally in favour of the proposed course outline in Physical Science if the conditions specified in the introduction were brought into effect.

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